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ABSTRACT

The launch of Sputnik by the Soviet Union in 1957 initiated a series of reform movements in mathematics education. These reform movements provide a framework from which to chronicle the development of interest into gender differences in mathematics learning. The paper examines these issues and is presented in six sections. The first section discusses the Sputnik crisis and the perceived shortage of people in scientific and technological fields that led to the reform movement referred to as the "new" or "modern" mathematics. The second section presents the changes in mathematics pedagogy that occurred during the 1960s and into the 1970s. Relevant topics during this time period were the changing demographics in the United States, ability grouping, and individualized instruction. The third section discusses the development of the relationship between technology and mathematics education and the recognition of the potential of computer use in the classroom. The fourth section discusses the relationship between mathematics and gender that grew as educators began to focus on meeting individual needs of students and as the Women's Liberation Movement gained force. Research related to gender differences in mathematics education is presented. The fifth section raises questions about the mathematics education research in the field and the ability to identify which gender differences do in fact exist. The final section summarizes the findings and proposes that the research seeking to determine the origin of gender differences may contribute to the beliefs that differences do exist. (Contains over 50 references.) (MDH)

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Gender, Technology, and Mathematics Education: Working Together to Achieve "Equality"

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> Mention mathematics to a woman and she freezes into a condescending attitude of tolerance - she knows it exists, she uses it when she must, but it certainly has very little to do with her own delightfully imaginative and delicate world of interests. (Weber, 1957; quoted in Sommer, 1958)

The launch of Sputnik by the Soviet Union in October of 1957 helped to initiate a crisis in mathematics and science education from which these fields have yet to fully emerge. The launch extended popular perception of the scope of the Communist threat beyond nuclear attack to widespread technological obsolescence, and increased participation of students in mathematics and science education came forth as the popular solution.

One aftermath of the Soviet launch was the beginning of a long parade of widely-touted reform movements in mathematics education designed to increase participation, the most notorious of which was "new math." New math was succeeded, perhaps not rapidly enough, by other efforts, most recently that presented by *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics (NCTM), 1989) and *Professional Teaching Standards for School Mathematics* (NCTM, 1991).

The historical sketch of three decades, beginning with Sputnik, of reform in mathematics education which is presented here is designed to provide a framework from which to examine the development of interest into gender differences in mathematics learning. This historical grounding is critical, for not only did this period mark a dramatic increase in concern over education in

general, and mathematics education in particular, it also saw the emergence of the Women's Liberation Movement, and widespread popular and academic interest in questions of gender, class, and race. The intersection of these two events, reform in mathematics education and the women's movement, sparked the development of interest in the field of gender and mathematics education to the degree that the relevant literature has become an almost unintelligible mountain of words, contradictory and confusing.

It is hoped that the present work will allow one view of the origins of the mountain that is instructive rather than overwhelming, and that this view will assist in understanding how the current questions in mathematics and gender are framed, both presently and historically.

SPUTNIK, THE EMERGENCE OF CRISIS, AND THE "NEW MATH"

In the post-war 1950s, the United States basked in the glow of a decisive win and Americans began to accustom themselves to the luxuries of technological innovation. Magazine pages were filled with advertisements extolling the latest in labor-saving devices; scores of comic books and motion pictures explored the (then) outlandish possibilities of tomorrow's science. However, Communists of the most despicable type roamed the world freely; concerned American citizens built bomb shelters and installed the newest home technology.

The prevailing attitude of confidence in our technological superiority was shattered in October of 1957 when the Union of

Soviet Socialist Republics launched Sputnik, the first Earth-orbiting satellite.

> Ever since the Russians launched their Sputnik, gloom has descended on the American Horizon. Public opinion, aroused by this event, found a ready answer to the complaint that we had failed to train enough scientists and technicians. The fundamental cause of our suddenly discovered inferiority was ... our educational system (Magyar, 1961; 293).

Already concerned with a lack of "manpower" in scientific and technological arenas (Cooper, 1985; 128), the countries of the West stepped up efforts to reform mathematics and science education. Both this concern and the activity that followed were intensified by the public's fear of Communism and fueled by the release, at least in the United States, of massive public funds for reform (Moon, 1986; Kliebard, 1987).

Prior to Sputnik, mathematics educators in the United States had been engaged in developing programs to meet "the needs of society ... [and] ... the needs and characteristics of the pupil" (Kinney and Purdy, 1952; 31). However, questions about content, and scope and sequence in mathematics education had begun in the early years of the decade to focus on "modern" mathematics, or "new math," as the needs of students became increasingly subordinated to the needs of society for more mathematicians and scientists. Arguing that only the "content of the [mathematics] courses hadn't changed in the last 300 years" (Sharp, 1964; 11), reformers in mathematics education escalated their efforts to "modernize" the mathematics curriculum. This modern curriculum, it was believed,

would meet the needs of students living in a constantly-changing, technological world.

Herbert Kliebard (1987) notes that these reform efforts were not controlled by the education community, but by mathematicians and scientists who were the recipients of the bulk of available federal funds. This period of reform marked the entry of the federal government into curriculum revision, heretofore considered a more local endeavor (Kliebard, 1987; 268). Moreover, concern about technological progress prompted the outbreak of new worries about the education American students were receiving. Comparisons between the educational systems of the United States and the Union of Soviet Socialist Republics suggested that, while Soviet students studied mathematics, physics and chemistry, talented American minds were being wasted in "life development" courses, where students learned how to bake pies and "get along with their peers" (Kliebard, 1987; 265).

CHANGES IN MATHEMATICS PEDAGOGY

Understanding the nature and scope of the changes that were perceived by both educators and parents in the early 1960s is central to the present project. Not only had the structure and relations of the world's governments been altered by World War II and the development of the Cold War, the school population was increasing both as the population increased and as more students stayed in school through graduation (Philadelphia Suburban School Study Council, 1964; 9-10). The gains made by supporters of

integration, beginning with *Brown v. Board of Education of Topeka, Kansas*, foretold of further changes in the demographics of the school population (Howes, 1970b).

The launch of Sputnik, and the availability of funds that it triggered, had contributed to concern about both kinds of exceptional students, those identified as talented as well as those considered "underprivileged" (Griffiths and Howson, 1974; 138). Initially, most effort had been devoted to the mathematics education of talented students; as the demographics of the school population changed, more attention was given to identifying disadvantaged students, determining the needs of such students, and meeting those needs in the mathematics classroom (Troisi; Stovall; Mintz; Pflaum; Sobel, 1967). However, a few argued that good mathematics education for all students would meet the needs of "non-achievers" and "culturally disadvantaged" students (Davis, 1967; 12), and that special attention for these, mostly minority and/or urban, students was not necessary.

In the attempt to provide a strong education for all students, considerable effort was devoted to exploring the classroom practices and theoretical assumptions surrounding ability grouping. A practice that had been gaining momentum since the 1930s (DeHaan and Doll, 1964), ability grouping was the most commonly-used method of grouping students to maximize achievement (Weaver, 1961) and, in the 1960s, it increasingly came under attack. Groups of students arranged homogeneously by one standard, it was argued (Goodlad and

Anderson, 1959; Weaver, 1961) were certainly heterogeneously grouped by other standards. Goodlad and Anderson (1959) add:

> The greatest variation occurs, usually, for children at the top and bottom of the achievement continuum. And yet, paradoxically, when grouping by ability levels is proposed in educational circles, it is invariably the gifted or the slow who are to be segregated into "homogeneous" groups (p. 15).

Concerns about the possibility of creating homogeneous groups of students led away from strict reliance on academic ability to plans to groups students in other ways. Additionally, the worry that ability grouping contributed to a "wastage of talent" among students of "lower ability" (Kelly, 1978; 10) hastened the move to other ways of differentiating methods, assignments, and rate of progress along a continuum from highly individualized to flexible groups to whole class (Goodlad and Anderson, 1959; Melby, et. al., 1964; Howes, 1970b; Duker, 1972).

General dissatisfaction with ability grouping propelled the mathematics education community to embrace individualized instruction as the pedagogic key to reaching masses of students who were failing or rejecting mathematics courses. The period from the mid-1960s to the late 1970s showed a significant number of educators proclaiming the virtues of a individualized mathematics program which would not only allow for differences in learning rates, but allow students to pursue "personal investigations ... which develop from problems children face as they explore the environment" (Howes, 1970a; v).

Schools were criticized for disregarding "individual differences among learners" and perpetuating practices that "accentuate rather that alleviate individual differences" (Duker, 1972; 20). Within the literature on individualized instruction, numerous differences in student ability and preparedness are highlighted: parental involvement, prior school experiences, participation in Head Start programs, military service of parent(s), sibling rank, maturity of student, health, and social status (West and Doll, 1964; Keuscher, 1970; Duker, 1972); these differences in students were believed to grow larger, not smaller, with time in school (Thomas and Thomas, 1965). In order to individualize instruction, "ways to permit the student to progress at his rate according to his style of learning and ways to motivate him to think creatively in formulating his mathematical concepts and knowledge of mathematics" had to be developed (Gibb, 1972; 394). A variety of possible ways were proposed: nongraded schools, departmentalization, Individually Prescribed Instruction (IPI), contracting, and computer-assisted instruction (CAI) (Goodlad, 1959; Howes, 1970; NCTM, 1970; Gibb, 1972).

TECHNOLOGY AND MATHEMATICS EDUCATION

One outstanding feature of individualized instruction is the sense of promise attributed to the electronic digital computer as the vehicle for realizing truly individualized instruction (Darnowski, 1970; Suppes, 1970). The power of the computer lay in its ability to rapidly record and respond to student errors, and to

supply instructional tasks to rectify those errors, all without the intervention of the teacher. Unfortunately, the difficulties and expenses involved in bringing computers into every classroom, or even every mathematics and science classroom, have not been overcome at the rate assumed by mathematics and science educators in the 1970s; wide-spread computer-assisted instruction is only now becoming a reality (Apple, 1988).

There are actually multiple representations of computer technology (which can be extended to a broader sense of technology), in educational literature. In addition to the computer as a instructional device, concerns about mathematics education for an increasingly technological world (Atkinson and Wilson, 1970; Howes, 1970c; Suppes, 1970), which have claimed larger and larger portions of educational reform efforts since the beginning of the century (Noble, 1988; 243), suggested that new skills were "necessary for adaptation to constant technological and occupational change (Noble, 1988, 242). Indeed, there is continued belief among educators that "'high tech'... will save our students and teachers" (Apple, 1988; 291) as computers allow education to accomplish its goals more effectively and efficiently (Noble, 1988; NCTM 1989).

Even as educators were moving from individualizing instruction by ability grouping towards a recognition that "all teaching ... is mixed ability teaching," (Ridley, 1982; 37) meeting the demands of living in a technological world remained central (Kelly, 1978). Technological changes demanded that everyone be educated to maximum

potential to keep up with the technology; the educational system "must be productive of adaptable citizens" (Kelly, 1978; 23) who can live with today's technology, as well as accept that such technology is destined to be obsolete.

The sense of crisis in mathematics education that burst on the public scene following the launch of Sputnik re-appeared in 1983 with the report of the National Commission on Excellence in Education, *A Nation At Risk*. Once again, our "preeminence in commerce, industry, science, and technological innovation" (NCEE, 1983; 5) was threatened by an educational system too inadequate to properly prepare students for the world in which they lived. Though now couch in less militaristic and more economic terms, this is much the same crisis that emerge following Sputnik.

MATHEMATICS EDUCATION AND GENDER

It is interesting and disturbing to note at this point that few references have been made, both in the mathematics education literature and in this paper, to gender differences in learning mathematics. Even as educators became more concerned with individual differences in learning mathematics, gender seems to have been of slight curiosity.

Indeed, in the period from the mid-1950s to the early 1970s, researchers in mathematics education expressed concern with why "Johnny" could not add (Fang, 1968). Common wisdom of the time stated that, while Johnny cannot read either, mathematics is "his" strength, whereas language is the strong subject for Jane. Maccoby

(1966; also, Maccoby and Jacklin, 1974) concluded from the literature on sex differences that, although there was no clear indication that either sex was generally more intelligent than the other, there was sufficient empirical evidence to support the belief that girls have superior verbal ability and, in the long term, inferior abilities in arithmetic reasoning, spatial ability, and the ability to creatively restructure problems.

This conclusion was supported by the data collected for Project TALENT, a large-scale testing effort designed to identify talented high school students (in the spirit of post-Sputnik concerns). Project TALENT tested hundreds of thousands of high school seniors in 1960, and included interest and attitudinal inventories in addition to the battery of academic tests, which focused primarily on mathematical, scientific, and technical aptitudes. Like other research on sex differences, the Project TALENT data indicated that, among high school-aged students, boys were much more likely than girls to have interests and abilities in quantitative and/or scientific areas.[1]

As educators began to focus on meeting individual needs and women began to demand equality of access and of pay (among other things), it is not surprising that concern for gender discrepancies in mathematics education arose as part of the research agenda. The bulk of such research in the 1950s and 1960s seems to have been less directed at ways to increase the mathematical abilities of

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[1]Wise, Steel, and MacDonald (1979) found that differences in the number of mathematics courses taken by female and male students accounted for virtually all the discrepancies reported in the Project TALENT data.

young women than to determining appropriate expectations of students based on gender. For example, a study reported in *Journal of Educational Psychology* (Sommer, 1958) suggests that women are not capable of remembering quantitative information contextualized in a paragraph with the same accuracy as men, although the same women demonstrated ability at recalling decontextualized numbers of six or seven digits equal to that of men. Sommer concludes that this may indicate that "many women are unable to retain large numbers (thousands or millions)" (1958; 191), in spite of his own research data. Clearly, the women were able to retain numbers in the millions, for they recalled the six- and seven-digit numbers at the same rate as the men in the study. The problem with the recall of the women was not, it would seem, in remembering the numbers themselves as Sommer concluded, but in the context in which the numbers were presented. For instance, it may be easier to recall a seven-digit number presented out of context if one likens it to a phone number. However, when the same number is presented as the population of Bombay or as the number of barrels of oil shipped from Venezuela each month, the lack of familiarity or interest in the presented material, or others distractions of context, may account for some of the observed discrepancies.[2]

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[2]It is interesting to note that the type of error Sommer highlights is one of significant places; i.e., writing 12,000 for 120,000 or 1,016,000 for 116,000. It has been suggested (Paulos, 1988, 1991) that most people have difficulty interpreting and remembering large numbers, due in large part to a general lack of understanding differences in the magnitudes of large quantities.

Sommer's study is mentioned here to illustrate[3] that gender research in mathematics education prior to the early 1970s was not limited to mere statements of male superiority in mathematics and science. Some effort was expended to determine which gender excelled in broadly conceived areas of mathematics. However, the research on women and mathematics that was conducted in the 1950s and 1960s did have a flavor of sexism. In other words, the (primarily male) researchers did evince a propensity for "showing" the inferiority of female mathematics students.

In the 1970s, interest into the relationship between education and gender blossomed with the advent of the Women's Liberation Movement. Recognizing mathematical training and ability as a critical element in obtaining employment in heretofore "male" domains like medicine and engineering, academics began to question the simple explanations for female underachievement and underparticipation in mathematics. In 1974, Elizabeth Fennema looked to the research in gender differences in mathematics learning, revealing an inconclusive body of evidence, particularly for young children. Elizabeth Fennema and Julia Sherman (1977; 1978; Sherman and Fennema, 1977) further showed that prior research on gender differences in mathematics had failed to control for level of mathematical experiences, with males typically having higher levels of mathematics education, which could account for observed gender differences.

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[3]Sommer is used here illustratively; Fennema (1974) provides a summary of major research in mathematics education and gender conducted in the 1960s.

Fennema and Sherman proceeded to challenge common perceptions about gender differences by investigating the amount of time spent in mathematics-related tasks outside of school, as well as developing instruments to measure affective variables related to mathematics achievement (Fennema-Sherman Mathematics Attitudes Scales, 1976). In the (nearly) two decades since Fennema and Sherman propelled the mathematics education community to reexamine the origins and development of gender differences, numerous hypotheses have been tested, and various intervention strategies developed to alter the patterns of behavior of female mathematics students and mathematics teachers. However, in this time, significant improvements in the participation or achievement of female students in mathematics cannot be claimed.

Indeed, in the same time period, no significant improvements in the achievement or participation of mathematics students of either gender can be claimed. This is in part the significance of the historical sketch presented at the beginning of the paper. In a period of massive reform efforts, involving noteworthy resources in the form of federal funds, little improvement was made in the popular perception of mathematics as useful, important, or valuable. As Rodgers (1990) notes, the evidence shows that an enormous portion of <u>all</u> learners end their mathematics education with feelings of fear, helplessness, and guilt, believing that mathematics is something which must be endured, not enjoyed, and abandoned as soon as possible.

In general, it is agreed that female students are less likely to pursue higher mathematics to the same degree as males, although there are serious questions about the validity of evidence upon which this claim is based. Gilah Leder (1990) notes that males are more likely to drop out of secondary schooling than are females, and that therefore "the educational disadvantage faced by females does not lie in the retention domain" (p. 11). While the statistics may favor females in school-retention, these same statistics may spell doom for females in mathematics education research. If young men are more likely to leave school than young women, then any comparison of males to females which requires them to be in school is necessarily a comparison of a more-select group with a less-select group. Such a research bias seems unavoidable in strictly school-based research, which the vast majority of the research in mathematics education and gender expressly is, for we concede that "mathematics is learned, for the most part, in classrooms" (Fennema, 1990; 6).

Chipman and Thomas (1985) note that gender differences in mathematics participation (defined by pursuing a mathematics major in college) are relatively small; larger gender differences are found in related technological and scientific fields. Furthermore, the available evidence increasingly suggests that differences between females and males in mathematics do not exist (Hyde and Lynn, 1986; Damarin, 1990). In fact, the proportion of women completing undergraduate degree programs in mathematics is nearly

equal that of men, and is nearly equal to the proportion of all women who receive bachelor's degrees (Chipman and Thomas, 1985).

However, popular perception of the differences has held that men perform better in mathematics, due in large part to publicity received by some studies such as the work done by Benbow and Stanley (1980), more recently, the report of the American Association of University Women, *How Schools Short Change Girls* (1992). What research into gender differences in mathematics, and its popularization, fails to consider is the relationship between the perceived technological crisis which mathematics and science education must meet and the attention to recruiting female students into mathematics.

WHICH DIFFERENCES EXIST?

An interesting question which is rarely asked, at least explicitly in the mathematics education literature, is whether or not differences in the mathematical ability of males and females exist. Rather, researchers are busy trying to decide to what extent there is a difference, what causes it, and when it happens, assuming the difference to be real. However, the data is inconclusive and contradictory, owing in large part to the complexity of the relations between students, teachers, schools and society.

Questions about the basis of research in gender and mathematics education are raised by Valerie Walkerdine (1990): "What ... is lurking behind the desire to prove the mathematical

inferiority of girls?" (p. 1). Central to answering this question is an awareness of the broader educational and cultural climate out of which concern over technological obsolescence arose. As Sputnik popularized this concern, the Women's Liberation Movement gave birth to genuine interest in the education of women. In the intervening years, these two concerns have become central to the goals of mathematics education. In the introduction to *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) both mathematics education for a technological world and equal opportunities for women and minority students are highlighted:

> Women and most minorities ... are seriously underrepresented in careers using science and technology. ... *We cannot afford* to have the majority of our population mathematically illiterate. Equity has become an *economic necessity* (p. 4; emphasis added).

Concerns about gender equity in mathematics education stem from this sense of crisis in science and technology. This anxiety about our technological future has found a toehold in differences based on gender: in order to increase the number of mathematicians, scientists, and technologists, we need only to increase the proportions of female and minority students in mathematics.

A series of studies by Mary Poplin (1991) looked at "the concerns over women's underachievement (as compared to men's) in mathematical and computer pursuits" (p. 1). After identifying women with high mathematics aptitude, Poplin interviewed those who had not selected mathematical or technological careers. All were aware of the advantages, particularly financial, of mathematics- or computer-related careers; Poplin concluded from the interview that

these "women ... [made] self-conscious and well-informed choices about not participating in math ... [and were] not simply manipulated by society" (p. 23). As a result of these conversations,

> I have been convinced ... that their disinterest is an actively constructed one [and] I am more cautious in my pronouncements that we simply must get more women into math ... I, like many feminists, am wondering if it would not be more profitable to strive to upgrade the status of the fields women enjoy than to try to change our ourselves and our interests to match more nearly those of men (pp. 24-25).

CONCLUSION

We have accepted the crisis of Sputnik as truth: our problems, perhaps now more economic and corporate than militaristic, can be resolved through technological progress. The solution to the threat of technological obsolescence is to increase the number of technologists. As the population of schools has diversified, at possibly a faster rate than the larger population, concerns for the mathematics education of female and other minority students stem not from egalitarianism but from necessity.

It is into the technological crisis that research in gender and mathematics education has been subsumed. In serving the purposes of technological progress we have allowed our research questions to be determined for us. We have been steered away from looking to our definition of mathematics itself, and the cultural ideologies which support it. C. A. Bowers (1987) identifies four

models of educational liberalism, each of which sustains the "current cultural trajectory" toward technologization:

> neoromantic free classrooms, the engineered classroom in the Skinner-Taylor mold, the Deweyian classroom that teaches the method of scientific problem-solving, and the emancipatory, consciousness-raising pedagogy of Freire (Bowers, 1987; 162).

We have been directed toward more superficial questions about the gender differences in students, not the gender differences in mathematics. It is to these questions that we must turn, if understanding the relationships between gender and mathematics is our goal.

In the past 15-20 years, mathematics education researchers have endeavored to locate the origin of the differences. Some of the issues, like spatialization ability, have never been clearly linked to general success in mathematics. Linked to this is research on the neurobiology of the brain, and the lateralization of brain function. Since females perform better on tests of verbal ability, learn to read earlier, and evidence fewer verbal disabilities (stuttering, dyslexia), and because the left hemisphere of the brain specializes in verbal abilities, women are believed to be more left-dominant and men to be more right-brain dominant.

Stephen Katz (1988) provides an excellent critique of brain lateralization research. Looking to the research on brain-hemisphere specialization and gender differences in spatialization and verbalization abilities, Katz shows the theoretical and empirical inconsistencies and ambiguities present in the

literature. Furthermore, Katz argues that research of this type, especially widely-read and popular research (like much of the research in mathematics and gender) "emphasizes (and creates) *differences* between men and women while neglecting their overwhelming commonalities," noting that "only two percent of our total genetic material accounts for primary sex differences" (Katz, 1988; 34).

Such a statement is of particular importance when researching gender differences in mathematics. Do we, as well-trained and well-educated academic researchers, create differences between the genders when we conduct our research? Even if we fail to find significant differences, or even find differences that favor girls, given the popularity of the myth of gender differences in mathematics, does *any* research in this area perpetuate the belief in difference? For certainly, if there is sufficient reason to investigate gender differences in the mathematics classroom, then there must be differences to investigate, right?

In this paper, I have begun to examine the cultural milieu which gave rise to two decades of research on gender differences in mathematics. While much remains to be done, including consideration of the gendered nature of the kind of mathematical knowledge that is legitimated in schools, in order to tease out the subtle and complex relationships between women, men, teaching, learning, and mathematics, this historical lens provides us the means to begin to critique our own work.

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